ANS RPSD 2018 - 20th Topical Meeting of the Radiation Protection & Shielding Division of ANS
Santa Fe, NM, August 26 – 31, 2018, on CD-ROM, American Nuclear Society, LaGrange Park, IL (2018)

A Monte Carlo Model for the Evaluation of Shadow Shields used in Special Procedures and Cardiac Cath Labs

Robert L Metzger[1]

[1]*Radiation Safety Engineering, Inc, 3245 North Washington Street, Chandler, AZ 85225, rlmetzger@radsafe.com*

I. Abstract

A Monte Carlo model of a cardiac catheterization lab and a special procedures room has been developed to perform an a priori evaluation of staff doses resulting from fluoroscopy and digital imaging runs. Typical fluoro beam parameters and dimensions were used, and the staff collar doses with and without various available shadow shields were evaluated. Exact calculations of staff doses prior to a given procedure cannot be accurately calculated as the dose depends on the patient size and the complexity of the procedure. Estimates can be made, however, of the attenuation that would be provided by various shadow shields that are available in the institution.

II. Introduction

Many new invasive special procedures have been introduced in the last few years that result in dramatically improved patient outcomes, but require the use of long fluoro times and digital imaging sequences. Collar badge doses for the interventional radiologists and cardiologists that perform the procedures have climbed and now frequently exceed 10 mSv per month. The limit for the lens of the eye is currently 150 mSv per year (US), which is based on an estimated threshold dose of 5 Sv to induce cataracts of radiogenic origin. Recently the ICRP has suggested that this dose is too high and recommended that the dose to the lens of the eye be limited to 20 mSv per year[5]. There is resistance to this new suggested dose limit[4], as, while the epidemiologic evidence for cataract formation due to ionizing radiation exposure appears to be lower than the initial estimate of 5 Sv, it still does not support the 20 Sv suggested limit[4]. The American College of Cardiology has also developed an expert consensus document on the best practices for the use of ionizing radiation in cardiovascular imaging that covers patient and staff doses from these procedures[6].

The collar badges are exposed to scattered radiations only, which are directly proportional to the patient entrance dose. These doses vary widely based on the patient size, the beam characteristics of the Special Procedures Room being used, the complexity of the case, and the physician's technique[1]. Shielding for the medical professionals performing the procedures is provided by various types of shadow shields which must be positioned and used properly to be effective. The combination of these shields that can be used for a given procedure varies, as does the physician's tolerance of them. Direct measurements of the radiation fields and on-the-fly adjustment of the shields is normally not possible, as most all of the procedures require arterial access and there is no time for such measurements and adjustments.

II. Description of Work

A Monte Carlo model of the special procedures room that can be adjusted for the specific characteristics of the room and the procedure to be performed has been developed to allow an *a priori* assessment of the shadow shields available and the projected effectiveness of their use. The model consists of the ICRP 110[2] voxelized adult phantoms and realistic beam parameters and geometries. Detectors to measure the exposure at skin entrance (ESE), and the exposure rate at the collar of the radiologist(s) of different heights have been included with the objective of reducing the collar to ESE ratio as much as possible for a given procedure, radiologist, and room.

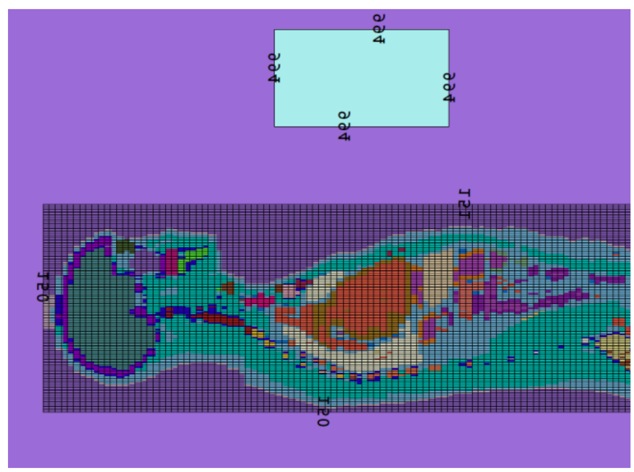

Figure 1 MCNP model of the cardiac cath lab consisting of the ICRP 110 adult voxelized phantom, the image intensifier, and Fluoroscopic beam (not shown).

The actual ESE for a procedure cannot be anticipated beforehand as the amount of fluoro and digital imaging that will be needed cannot be estimated prior to the start of the work. Consequently, arranging the various shadow shields to minimize the collar to ESE ratio is the best approach.

III. Results

The new model was used to assess the shadow shields available for a special procedure to place Y-90 microspheres in the liver to treat a metastatic tumor load for a male patient. The procedure requires extensive mapping of the vascular structure of the patient's liver prior to the introduction of the microspheres. This procedure is also exceptionally difficult to arrange shields to protect the radiologist due to the large size of the image intensifier and beam (typically 35 to 40 cm in diameter), and the close proximity of the imaged area to the radiologist stationed at the patient's groin. There is very little space between the edge of the image intensifier and the radiologist, and therefore little room to position the shadow shields effectively.

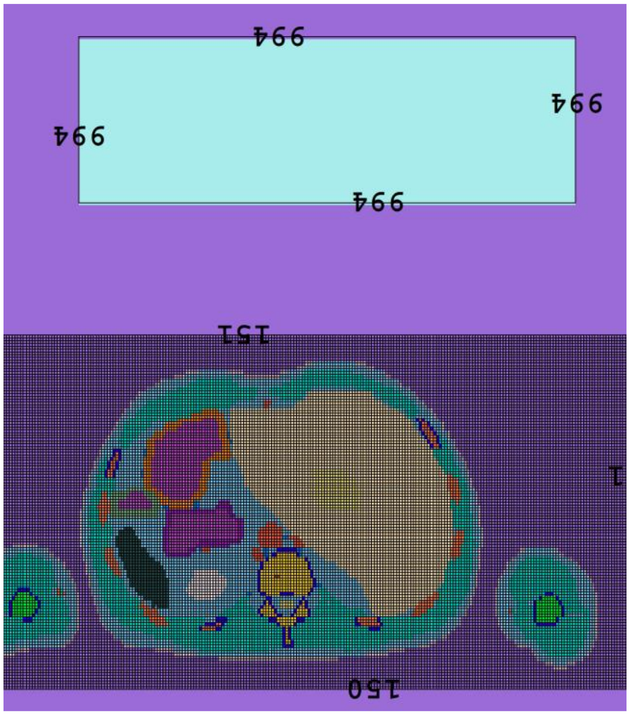

Figure 2 MCNP model for Y-90 radioembolization showing the large image intensifier centered over the liver of the voxelized phantom.

The model was developed for a 110 kVp diagnostic X-Ray beam from a three phase 12 pulse generator centered on the phantom's liver. The image intensifier had a 36 cm diameter entrance phosphor. Point detectors were placed at the skin entrance and at the collar height for the radiologist stationed at the patient's groin. The model was run under MCNP6[3] to determine the collar to ESE ratio for no shadow shield, a 0.5 mm lead plexiglass shield suspended from the ceiling in different locations, and a bismuth loaded flexible drape placed over the patient's abdomen. The results shown in Table 1 below, plainly showed the most effective combination and placement of shields for this procedure.

Note that not all shield combinations will be found acceptable by the radiologist as they are very close to the sterile field needed for the arterial access. Nonetheless, the radiologist can plainly see beforehand what shields are available and their effectiveness.

Using a high-end workstation with 40 threads dedicated to MCNP, each run of E7 photons converged in less than ten minutes. This makes the *a priori* evaluation of different shield combinations practical for each procedure that is requested.

Table 1 Collar badge exposure rate (mR/Hr) per R/min Exposure at Skin Entrance for the Y-90 radioembolization model as a function of shield type and radiologist height.

	Short	Medium	Tall
No Shield	7.5	5.9	4.7
Misplaced Plexiglas Shield	6.7	5.2	4.1
Properly Positioned Shield	0.4	0.32	0.3
Shield + Bi Drape	0.3	0.26	0.20

References

1. K. FETTERLY, et al.,, "Effective Use of Radiation Shields to Minimize Operator Dose During Invasive Cardiology Procedures," *Journal of the American College of Cardiology*, **4**, 10 (2011).

2. ICRP. "Adult Reference Computational Phantoms." ICRP-2009, International Commission on Radiological Protection (2009).

3. T. GOORLEY, et al., "Initial MCNP6 Release Overview", *American Nuclear Society*, **180**, 3 (2012).

4. C. Thome, et al, "Deterministic Effects to the Lens of the Eye Following Ionizing Radiation: Is There Evidence to Support a Reduction in Threshold Dose?", Health Physics, Vol. 114, No.3, pg. 328 (March 2018).

5. International Commission on Radiological Protection. ICRP statement on tissue reactions/early and late effects of radiation in normal tissues and organs—threshold doses for tissue reactions in a radiation protection context. Oxford: ICRP; Publication 118, Ann ICRP 41(1/2):2012.

6.J.Hirshfeld,et.al.,"2018 ACC/HRS/NASCI/SCAI/SCCT Expert Consensus Document on Optimal Use of Ionizing Radiation in Cardiovascular Imaging: Best Practices for Safety and Effectiveness", *Journal of the American College of Cardiology*, in print, 2018.